

On the presence of a species of *Batophora* J. Agardh, 1854 (Chlorophyta: Dasycladales) in Formentera, Balearic Islands

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We report on the presence of a species of the genus *Batophora* in Estany des Peix (Formentera, Balearic Islands). The alga was first detected in spring 2020 when it bloomed in the northern side of the lagoon. According to morphological and reproductive characters the species has been tentatively identified as *Batophora occidentalis* var. *largoensis* (J.S. Prince and S. Baker) S. Berger and Kaeffer ex M.J. Wynne, although genetic confirmation is needed. Shipping seems the most plausible pathway of introduction. The sudden and rapid proliferation of *Batophora* in Estany des Peix points to an invasive behaviour of this alga. A future monitoring of the evolution of the invasion is highly recommended.

Keywords: *Batophora*; alien species; Formentera; Balearic Islands; Mediterranean Sea.

SOBRE LA PRESÈNCIA D'UNA ESPÈCIE DE *BATOPHORA* J. AGARDH, 1854 (CHLOROPHYTA: DASYCLADALES) A FORMENTERA, ILLES BALEARS. Donem a conèixer la presència d'una espècie del gènere *Batophora* a l'Estany des Peix (Formentera, Illes Balears). L'alga ha estat detectada per primera vegada durant la primavera de l'any 2020, quan ha crescut espectacularment a la riba nord de l'estany. En base a caràcters morfològics i reproductius, l'alga ha estat temptativament identificada com a *Batophora occidentalis* var. *largoensis* (J.S. Prince i S. Baker) S. Berger i Kaeffer ex M.J. Wynne, tot i que són necessaris estudis genètics posteriors per a confirmar-ho. El transport involuntari per vaixells sembla la forma més plausible d'introducció. La sobtada i ràpida proliferació de *Batophora* a l'Estany des Peix apunta cap a un comportament invasor de l'alga. Es recomana el seguiment de l'evolució de la invasió d'aquesta espècie.

Paraules clau: *Batophora*; espècie introduïda; Formentera; Illes Balears; Mediterrània.

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Introduction

The Mediterranean Sea is a hot spot for introduced and invasive marine species (Galil, 2000; Boudouresque, 2008) and at the world scale is the sea harbouring the

greatest number of introduced species (Boudouresque and Verlaque, 2002a). Macrophytes are a key component of Mediterranean coastal habitats as they provide shelter and food for a wide range of organisms living on rocky bottoms but also on seagrass meadows (Boudouresque,

2004; Rodríguez-Prieto *et al.*, 2013). Several species of macrophytes have been introduced into the Mediterranean, changing the seascape and compromising the current functioning of ecosystems when they become invasive (Boudouresque, 2008). The estimated number of introduced macrophyte taxa ranges between 80 and 128 according to different authors (Boudouresque and Verlaque, 2002a, 2002b; Cormaci *et al.*, 2004; Zenetos *et al.*, 2012), with a high percentage of invasive or potentially invasive species (Boudouresque and Verlaque, 2002b; Zenetos *et al.*, 2010). The arrival of new species into the Mediterranean Sea is worth mentioning because they can become a nuisance for the ecosystems they colonize. Even if a complete and successful eradication of an introduced marine species is very unlikely, its control is feasible (Boudouresque, 2008) and, therefore, early warnings are important. Here we report on an early detection of a green alga into a lagoon environment at the island of Formentera (Balearic Islands, Western Mediterranean), with the intention of engaging (a) a monitoring of its future extension, (b) a study on its effects in the habitats, and (c) the assessment of a possible control of the invasion.

Material and Methods

The presence of a previously unnoticed, dominant alga in the northern shores of Estany des Peix, a lagoon located in the north-western part of Formentera (Balearic Islands) (38° 43' 33" N, 1° 24' 45" E) was communicated by Daisee Aguilera in late October 2020, after the detection by José Alejandro Figueiras Pérez in May 2020. A visit to the site was performed in November 6th, 2020. A snorkelling survey was made in the shallowest waters of the northern side

of the lagoon, close to the entrance (38° 43' 56" N, 1° 24' 51.3" E). Notes regarding the distribution of the previously unnoticed alga and the accompanying species along a shore length of 150 m were obtained. Several specimens were photographed (Olympus TG6 camera) and collected for later description in the laboratory. Specimens were maintained alive and transported in sealed plastic bags devoid of water to the laboratory. Once in the lab, specimens were maintained in a close circuit seawater aquarium. Description was performed using a Wild M8 Heerbrugg stereomicroscope and a Zeiss Axioplan light microscope. Photographs were obtained using an Olympus TG3 camera. Vouchers have been deposited at the Herbarium of the University of Girona (HGI 20826).

Results

During our visit to Estany des Peix, a species corresponding to the genus *Batophora* was clearly distinguishable as the dominant species in the northern shores of the lagoon, just after the channel that connects the lagoon to the open sea. Although we did not make any extensive survey, our samples were collected close to shore, in the upper infralittoral zone, always above 60 cm depth. Other species were present in the same habitat, such as the green algae *Dasycladus vermicularis* (Scopoli) Krasser, *Caulerpa prolifera* (Forsskål) J.V. Lamouroux, *Acetabularia acetabulum* (L.) P.C. Silva and several species of the genus *Cladophora* Kützinger, the brown algae *Padina pavonica* (L.) Thivy and *Dictyota mediterranea* (Schiffner) G. Furnari and the red alga *Polysiphonia opaca* (C. Agardh) Moris and De Notaris.

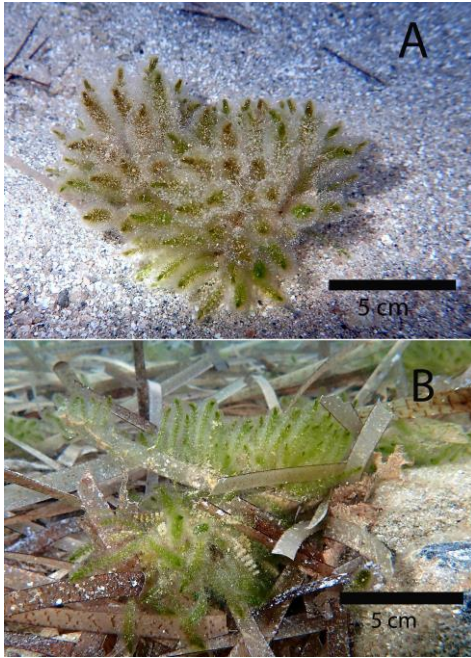


Fig. 1. Habit of the plants growing over rubble (A) and dead seagrass leaves of *Posidonia oceanica* (B).

Fig. 1. Aspecte de les plantes creixent sobre pedruscall (A) i sobre fulles mortes de *Posidonia oceanica* (B).

The description of the collected specimens is as follows. Thallus formed by creeping rhizoids and large numbers of simple, green to reddish brown, cylindrical stalks arising from them (Fig. 1, A and B). Rhizoids are attached to rocks, rubble, decomposing seagrass leaves or any kind of artificial substrate (ropes, plastic). Stalks clothed with soft whorls of six to ten lateral ditrichotomous branchlets, together forming a fuzzy cylinder 5-6 mm in diameter, 40-50 mm long (Fig. 2A). Main axis of the stalks measure 450 to 600 μm in diameter and the proximal node of the whorl branchlets measures 600-700 μm long and 140-180 μm in diameter (Fig. 3A). Each branchlet forks 6-7 times, decreasing in diameter

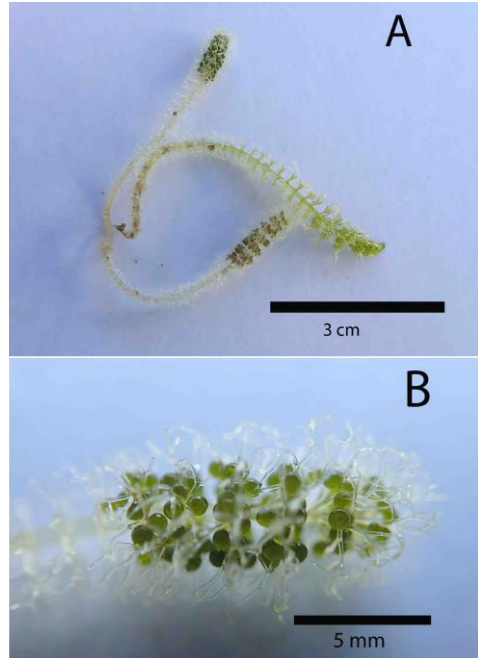
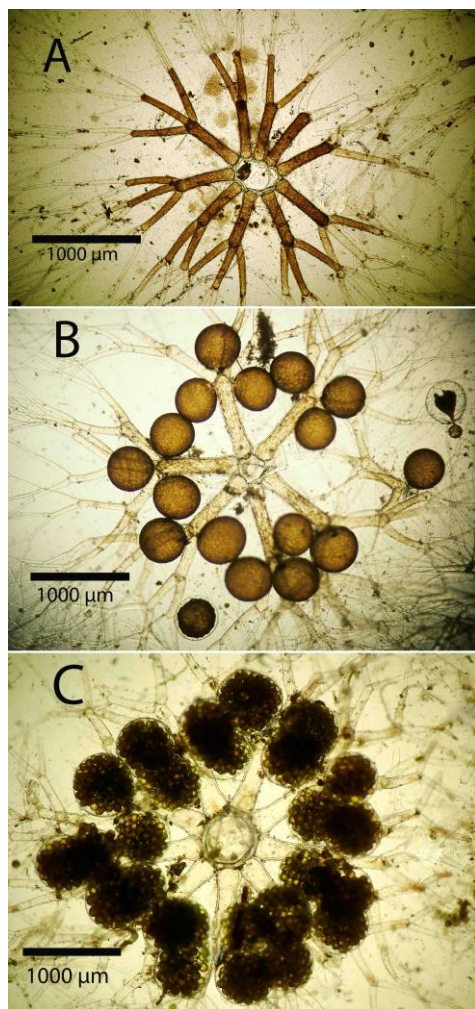


Fig. 2. A: Habit of one sterile surrounded by two fertile stalks; fertile areas are easily noticeable at the tip of the stalks by its dark green colour. B: Close-up of the fertile upper part of the stalk, holding the dark green, spherical gametophores.

Fig. 2. A: Aspecte d'un tal·lus estèril envoltat de dos de fèrtils; les àrees fèrtils són fàcils de distingir pel seu color verd fosc. B: Detall d'una part superior fèrtil amb els gametòfors esfèrics de color verd fosc.

from the proximal to the distant nodes, the terminal 3-5 nodes very thin, hair-like (Fig. 3A). Whorls separated 0.8-1.2 mm from each other in the medium part of the stalk, more densely packed in the upper and lower layers (0.5 to 0.6 mm between whorls). The basal, older, whorls lose their terminal nodes (mainly in reproductive stages) in the lower 7-15 mm of the stalk (Fig. 2A). Reproductive stalks bear densely packed gametangia into spherical to slightly ellipsoidal structures called gametophores (Fig. 2B). Gametophores grouped on the



upper (1/4) part of the stalk, with the fertile part of the stalk measuring 9 to 11 mm long (Fig. 2B). Gametophores mostly attached to the distant part of the proximal node of the whorl branchlets, only exceptionally to the second node (Fig. 3, B and C). When fully developed, gametophores are almost spherical, (440)-500-600-(650) μm maximum diameter (Fig. 4A). Gametangia are spherical, measuring (60)-65-(70), exceptionally 80-87 μm in diameter when

Fig. 3. A: Cross section of a sterile stalk showing the central main axis holding a whorl of ten lateral ditrichotomous branchlets, swiftly decreasing in diameter from the proximal to the outer nodes, the last ones becoming hair-like. B: Cross section of a fertile stalk with immature gametophores. C: Cross section of a fertile stalk with mature gametophores.

Fig. 3. A: Secció transversal d'un tal·lus estèril on es distingeix un eix principal central amb un verticil de deu branques laterals que es divideixen di- o tricotòmicament i que redueixen el seu diàmetre des de les parts proximals a les més externes, les darreres en forma de pèl. B: Secció transversal d'un tal·lus fèrtil amb gametòfors immadurs. C: Secció transversal d'un tal·lus fèrtil amb gametòfors madurs.

mature (Fig. 4, B and C). Biflagellate gametes show an elongated convex form and measure 5x12 μm .

Discussion

Two species are currently recognized inside the genus *Batophora*: *B. oerstedii* J. Agardh and *B. occidentalis* (Harvey) S. Berger and Kaever ex M.J. Wynne. There is much confusion regarding the specific characters that allow the distinction between *B. oerstedii* and *B. occidentalis* with contrasting features among authors, even in the reproductive characteristics, the only ones valid to make a proper identification of the species (see: Berger and Kaever, 1992; Gómez-Poot *et al.*, 2002; Qua-Young *et al.*, 2006; Rodríguez-Reyes *et al.*, 2018). After a thorough revision of the literature, it seems that the main diagnostic character that distinguishes *B. oerstedii* from *B. occidentalis* is the position of the gametophores, restricted to the proximal node in *B. occidentalis* but present in the proximal but also on the second node in *B. oerstedii* (Bonotto and Lüttke, 1980; Berger and Kaever, 1992). This character would unequivocally identi-

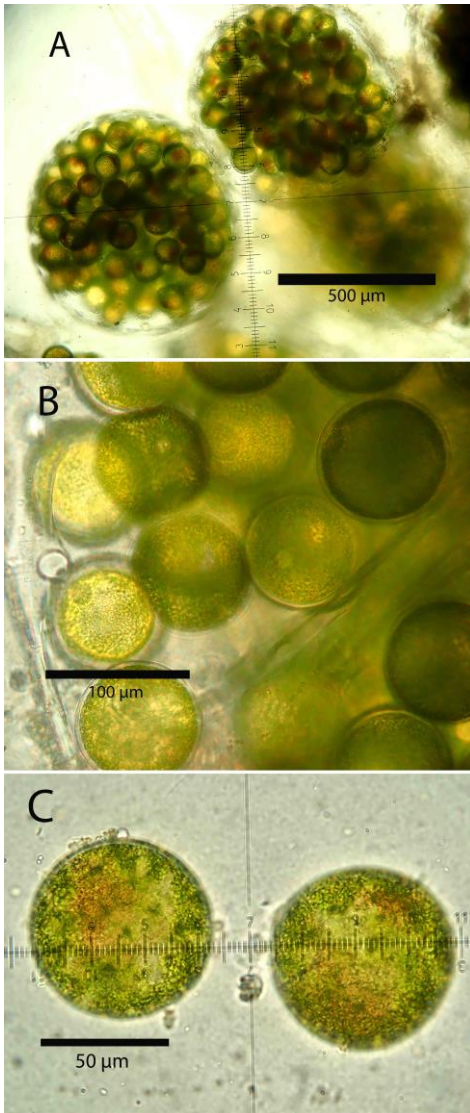


Fig. 4. A: Mature, nearly spherical gametophores holding a great number of densely packed gametangia. B: Detail of gametangia inside a gametophore. C: Two mature gametangia.

Fig. 4. Gametòfors madurs, pràcticament esfèrics, amb un gran nombre de gametangis al seu interior. B: Detall dels gametangis a l'interior d'un gametòfor. C: Dos gametangis madurs.

fy the specimens from Estany des Peix as *B. occidentalis*. However, a third species was described by Prince and Baker (1984a; 1984b): *Batophora largoensis*. According to Berger and Kaever (1992) *B. largoensis* and *B. occidentalis* crossbred and gave a new fertile generation, while *B. largoensis* did not crossbreed with *B. oerstedii* (Prince and Baker, 1984b); therefore, *B. largoensis* was transferred to the entity *B. occidentalis* as a variety (Berger and Kaever, 1992). The specimens collected in Estany des Peix match with the original description of *B. largoensis* by Prince and Baker (1984a), although the gametangia of the plants collected in Formentera are larger than those reported in the original description (60 to 87 versus 50 µm in diameter). Gametophores are also slightly bigger, although in the range of the original description (Prince and Baker, 1984a) and in the ranges provided by other authors (Littler and Littler, 2000; Dawes and Mathieson, 2008; Rodríguez-Reyes *et al.*, 2018). According to the last revision of the genera *Batophora* by Rodríguez-Reyes *et al.* (2018), where the three *Batophora* entities are compared, our specimens correspond to the variety *largoensis* because the whorled branchlets are completely deciduous only in a small part of the older fertile stalks and because gametophores are spherical, never ovoid as they usually are in *B. occidentalis*. Thus, the taxa found in Estany des Peix is most likely *Batophora occidentalis* var. *largoensis* (J.S. Prince and S. Baker) S. Berger and Kaever ex M.J. Wynne (Wynne, 1998). This variety has been reported so far from the Gulf of Mexico (Prince and Baker, 1984a), the Caribbean Sea (Littler and Littler, 2000), Cuba (Suárez *et al.*, 2014), Martinica (Delnatte and Wynne, 2016) and the tropical western Atlantic (Wynne, 2017). Further genetic analyses are required

to confirm our identification following morphological characters.

The benthic assemblage that is being colonized by *Batophora* was characterized by Ballesteros *et al.* (2008) under the name “Lagoonal assemblage of photophilic algae” and corresponds to the habitat “Sheltered infralittoral rock, well illuminated, without Fucales, with *Dasycladus vermicularis* and *Acetabularia acetabulum*” (LPRE code 0301030702) (Templado *et al.*, 2012; Ballesteros and Cebrian, 2015; Ballesteros, 2019). This habitat closely agrees with the one reported for *Batophora* spp. by several authors on the tropical and subtropical Atlantic coasts, the Caribbean and the Gulf of Mexico: quiet waters of lagoons, inlets and estuaries (Taylor, 1960; Gómez-Poot *et al.*, 2002; Rodríguez-Reyes *et al.*, 2018). In its native distribution area, *Batophora* spp. also grows on submerged roots of mangroves, is very resistant to desiccation and inhabits waters with a large range of salinity and nutrients (Littler and Littler, 2000; Marciano *et al.*, 2014).

Outside the tropical and subtropical eastern Atlantic and adjacent seas, *Batophora* has been reported from Tenerife (Canary Islands) and Taranto (Mediterranean Sea). Samples collected in a tide pool from El Médano, Tenerife (Reyes *et al.*, 1993) were identified as *Batophora oerstedii* var. *occidentalis* (= *Batophora occidentalis*) based only in morphological characters of sterile individuals and, thus, identification has to be confirmed. The only Mediterranean record of the genus *Batophora* comes from Taranto (Apulia, Ionian Sea, Central Mediterranean) by Botalico, DelleFoglie and Perrone in Cormaci *et al.* (2004), who found some sterile, unidentified specimens. This citation has been questioned by Zenetos *et al.* (2005, 2010) because of insufficient

data. Our new finding of *Batophora* confirms the existence of this genus in the Mediterranean. The origin of introduction of *Batophora* in Estany des Peix remains unknown. Macrophytes are the leading group of introduced organisms in the western Mediterranean and their main pathway of introduction is shellfish aquaculture followed by shipping and aquarium trade (Verlaque, 2001; Boudouresque and Verlaque, 2002a, 2012; Zenetos *et al.*, 2012; Galil *et al.*, 2018; Boudouresque *et al.*, 2020). Since there are no shellfish farms in Estany des Peix and *Batophora* is not used in aquaria, the most likely pathway of introduction is shipping, probably via fouling of adult individuals or via ballast water transporting gametophores or gametangia. Formentera is a hot spot for luxury yachting, which has been listed as a pathway for species introductions (Hewitt *et al.*, 2007; Brine *et al.*, 2013; Cecere *et al.*, 2016). Several yachts that overwinter in the Caribbean come to the Mediterranean Sea in summer (Gui and Russo, 2011; Rodrigue and Notteboom, 2012). Even that it is not easy that a delicate alga such as *Batophora* can survive the Caribbean-Mediterranean transfer, yachting seems the most plausible explanation for the introduction of *Batophora* in Estany des Peix.

Batophora was first detected at the entrance of Estany des Peix by José Alejandro Figueiras Pérez on May 2020. The alga has progressed fast towards the inner part of Estany des Peix during summer and early autumn. The sudden and rapid proliferation of *Batophora* in Estany des Peix points to an invasive behaviour of the alga. In fact, this lagoon harbours other native Mediterranean algae present also in the Caribbean and the eastern tropical Atlantic such as *Dasycladus vermicularis*, *Caulerpa prolifera*, *Padina pavonica* or

Anadyomene stellata (Wulfen in Jacquin) C. Agardh (Littler and Littler, 2000; Ballesteros *et al.*, 2008), and even some invertebrates such as *Ecteinascidia turbinata* Herdman, 1880 (Carballo *et al.*, 1999). Thus, the environmental conditions of Estany des Peix seem suitable for Caribbean and eastern tropical Atlantic species, suggesting that is a good environment for *Batophora*. Future monitoring of the proliferation inside and also outside the lagoon is highly advised, as it will discern if *Batophora* is an introduced species of major concern in Formentera and other Balearic islands.

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